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To cite this article: Pham Huu Tan *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **630** 012014

IOP Conf. Series: Materials Science and Engineering **630** (2019) 012014 doi:10.1088/1757-899X/630/1/012014

A Miniature Study of Directional Couplers, Each with a Different Central Frequency

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Abstract. A study to determine how the operating frequency of the device during miniaturization depends on its efficiency and the safety of the original characteristics. It was found that the miniaturization efficiency decreases with increasing frequency. Thus, the design of compact couplers for Central frequencies from 1000 to 3000 MHz with a step of 500 MHz was studied. In this case, the dimensions in relation to the standard design were reduced by 78.8, 62.5, 46.7, 39 and 30%, respectively.

1. Introduction

The operating frequency of directional couplers affects their overall dimensions, the lower it is the larger the area occupied by the couplers. Therefore, at low frequencies it is necessary to apply miniaturization of all structural elements to obtain a device with acceptable dimensions. Miniaturization is to replace the standard segment with compact structure. In this case, these structures must have similar characteristics for the safety of the characteristics of the branch. It is also necessary to take into account how the Central frequency affects the effectiveness of this approach to reduce the geometric dimensions of the branch. In order to evaluate the existing experience of researchers in miniaturization, some articles were considered. In [1] proposed to reduce the size using quasi-concentrated elements, in [2] equivalent transmission lines, in [3] U-shaped capacitances, in [4] periodic capacitive loads, asymmetric T-shaped structures in [5], low-pass filters in [6,7,8], slow-down systems in [9,10], artificial transmission lines in [11-13], fractal structures in [14,15], in [16] high-resistance elements, in [17] loaded loops, in [18-21] interdigital capacitors. In this paper, we will investigate how the efficiency of the coupler at different Central frequencies changes with the same technique.

2. Design

Initially, the procedure was carried out to design standard designs of couplers at Central frequencies from 1000 to 3000 MHz in increments of 500 MHz. For all structures the same microwave material was used, with a permittivity of 4.4, a thickness of 1 mm and losses in the dielectric of 0.02. Figure 1 shows the topology of the coupler operating at a Central frequency of 1 GHz, and its frequency characteristics are shown in figure 2. The area of such a device is 2060 mm^2. The operating frequency band measured at the level of junction 20 dB is 110 MHz.

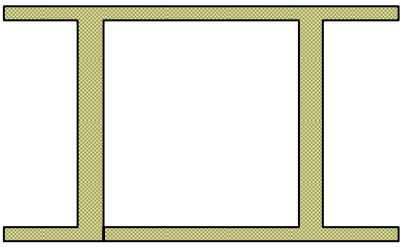

Figure 1. Topology directional coupler

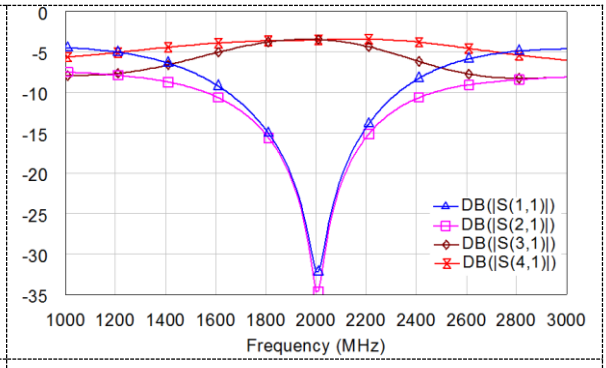

Figure 2. S-parameters from frequency

Standard designs were synthesized for all Central frequencies of 1000,1500,2000,2500 and 3000 MHz. After that, for all quarter-wave segments, the topologies of compact structures were calculated, which will be installed in place of standard segments. An example of such a structure is shown in figure 3. The frequency characteristics of such a structure are also presented in order to analyze its similarity with the characteristics of the quarter-wave segment (Fig. 4, 5).

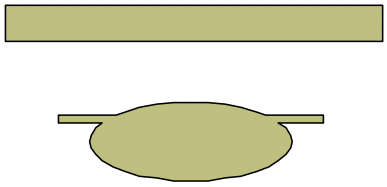

Figure 3. Topology of a quarter-wave segment and a compact structure with an impedance of 50 Ohm

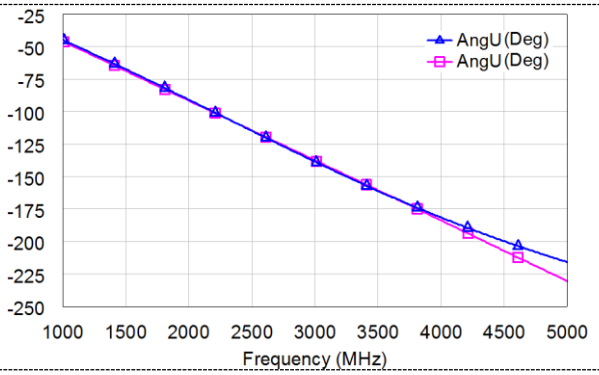

Figure 4. Phase on frequenc

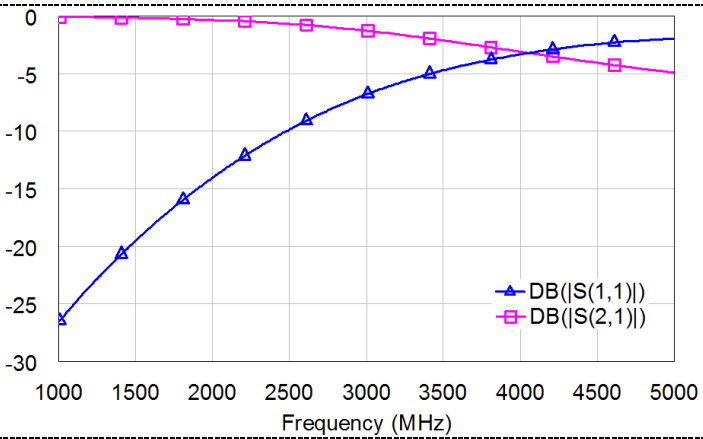

Figure 5. Frequency characteristics of a compact structure

It can be seen that in the required frequency range, for the coupler at the Central frequency of 1000 MHz, the structure coincides with the characteristics of the segment. After replacing all segments with compact structures, we obtained a compact design of the coupler at a Central frequency of 1000 MHz. The area of such a device is 435 mm^2, and the operating frequency band is equal to the value of 61 MHz. The topology is shown in figure 6 and the characteristics in figure 7.

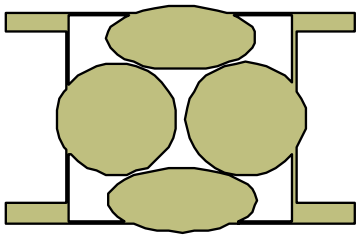

Figure 6. Compact coupler topology

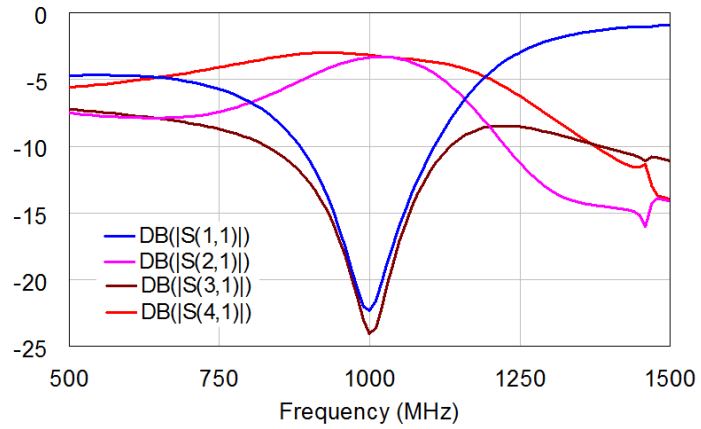

Figure 7. S-parameters from frequency

Compact coupler for a center frequency of 1500 MHz. The area of such a device is 376 mm2, and the operating frequency band is equal to the value of 121 MHz. The topology of the device is shown in figure 8, and its frequency characteristics are illustrated in figure 9.

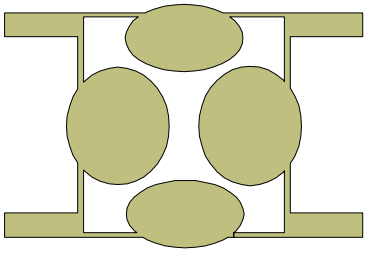

Figure 8. Compact coupler topology

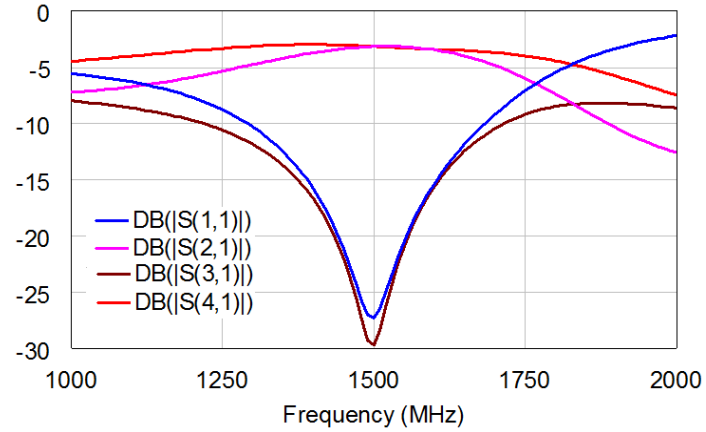

Figure 9. S-parameters from frequency

Compact coupler for a center frequency of 2000 MHz. The area of such a device is 332.9 mm2, and the operating frequency band is equal to the value of 160 MHz. The topology of the device is shown in figure 10, and its frequency characteristics are illustrated in figure 11.

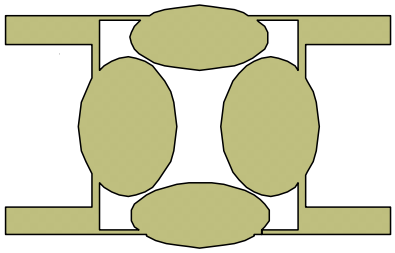

Figure 10. Compact coupler topology

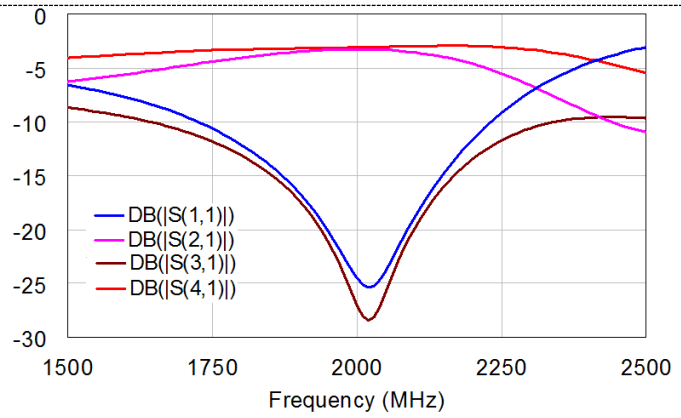

Figure 11. S-parameters from frequency

Compact coupler for a center frequency of 2500 MHz. The area of such a device is 265.3 mm2, and the operating frequency band is equal to the value of 195 MHz. The topology of the device is shown in figure 12, and its frequency characteristics are illustrated in figure 13.

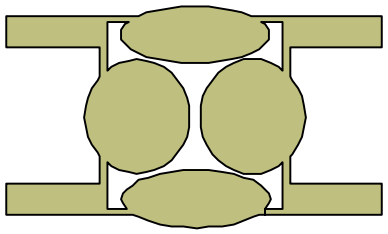

Figure 12. Compact coupler topology

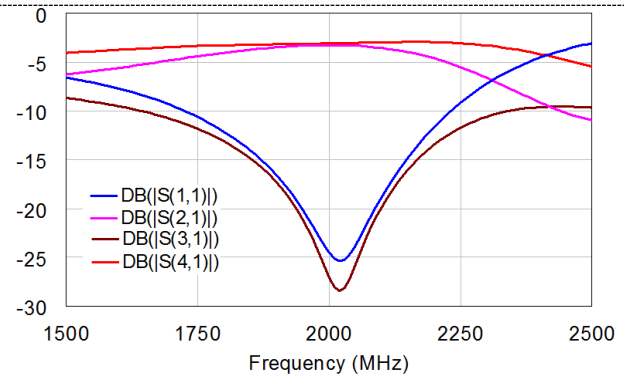

Figure 13. S-parameters from frequency

Compact coupler for a center frequency of 3000 MHz. The area of such a device is 229.46 mm2, and the operating frequency band is equal to the value of 234 MHz. The topology of the device is shown in figure 14, and its frequency characteristics are illustrated in figure 15. For comparison, the results were listed in table 1.

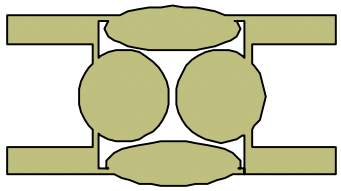

Figure 14. Compact coupler topology

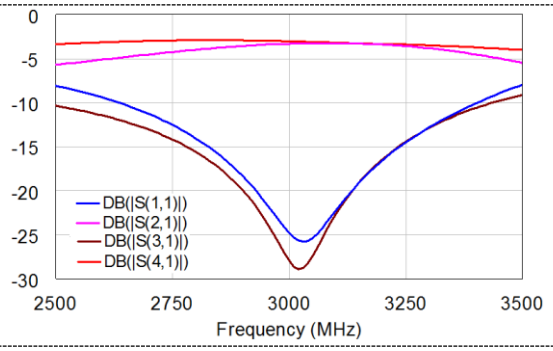

Figure 15. S-parameters from frequency

Table 1. Comparison of coupler

Frequency	Design	Area, mm2	Bandwidth, MHz	Reduce area, %
1000 MHz	Standard	2060	110	78.8%
	Compact	435	61	
1500 MHz	Standard	1005	168	62.5%
	Compact	376	121	
2000 MHz	Standard	625	224	46.7%
	Compact	332.9	160	
2500 MHz	Standard	435	273	39%
	Compact	265.3	195	
3000 MHz	Standard	324	321	30%

3. Conclusion

As a result of the study of how the Central frequency of the coupler affects the efficiency of the miniaturization method, it was found that with an increase in the Central frequency, the capabilities of the proposed miniaturization method decrease, since the area of the device at the Central frequency of 1000 MHz was reduced by 78.8%, and at a frequency of 3000 MHz by only 30%.

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